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Optical Programmable Processing Element Using Optical Fibers

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The purpose of this paper is to present a new type of Optically-Processing Element (OPE) based on the use of optical fibers as optical signal transmission medium. This device is able to process two signals, being its output two other logical signals. These outputs depend on two control inputs signals. Fourteen logic operations pairs are allowed with our circuit. Two nonlinear devices have been employed. The general scheme is shown in Fig. 1. A somehow similar all-optical programmable logic gate has been proposed previously [1], being one of the differences the transmission medium. The practical implementation of this gate [1] have shown one of the major problems with the technique of free-air transmission and on-axis addressing: all inputs need to be exactly collinear and of identical wavelength to produce the same characteristics for each input. As it will be shown these problems are not present in our system. Moreover our circuit is able to perform arithmetic operations such as addition, and to offer the possibility to implement an Optically-Programmable Digital Processor.

Fig. 1 is a schematic of the optical configuration of this Optically-Programmable digital circuit. Two optically bistable elements **P** and **Q**, described below, are used. The inputs to the circuit are two binary input signals, I_1 and I_2, and two holding or bias beams, *g* and *h*. These signals can be generated from common LED's, because no coherence requirements are needed. Signals I_1 and I_2 are fed to two optical fibers, combined by a 2 x 1 coupler and going through a single fiber. This combined signal is divided, with another 1 x 2 coupler, into two new optical fibers. Each one of these two new signals are again added to one bias beam, *g* or *h*. Signal going through path **1**, plus bias beam *h*, is the input of the optically bistable element **Q**. The output of this device is divided into two equal-intensity outputs, one going to the final port $\mathbf{O}_2$ and the other one, plus signal going through path **2**, is incident on the nonlinear device **P**. The resulting signal from this element goes to the final port $\mathbf{O}_1$.

The optically bistable elements can be similar to the employed by Wherret et al. [1]. In our case, both devices **P** and **Q** act as logical processors without being completely independent. Any bistable device exhibiting the above indicated responses shown could be used to implement this kind of logic circuits. Examples include GaAlAs MQW devices [2], ZnSe-based nonlinear interference filters [1] or liquid crystals based devices [3]. In our case, these behavior has been implemented optoelectronically.

By an appropriate choice of the power levels of the two optical bias inputs, *g* and *h*, all of the fourteen two-output logic functions corresponding to the two-input optical signals can be produced. Table I shows the logic functions that can be generated.

The main advantage of the present configuration is the possibility of a half adder, with an easy extent to a full-adder and a ripple carry-adder. This fact is of a great importance because the carry propagation in binary addition stands as a hindrance to the full utilization of the parallelism offered by optics. As it will be shown, the half adder is obtained on its basic configuration with the two controls signals to zero. Half-adder and Full-adder configurations are shown in Fig. 2.a-b, where M stands for the two bias inputs, *g* and *h*.

Other advantages of this proposal are, besides the implementation of a full-adder and fourteen pairs of possible logic operations, the use of optical fibers as signal transmission medium. In this way, pulses from different sources can be combined by using fiber couplers. If this fact is added to the smaller fiber losses, the device can operate now at relatively lower power levels that with other configurations. Timings can be easily adjusted by choosing the right fiber length. The whole system is now more efficient and rugged, reducing volume and cost.

In summary, we have proposed a new type of optical processing element able to perform different logical operations. The nonlinear components are interconnected by optical fibers. Hence, smaller losses at the system are present. A limited amount of parallelism can be obtained with optical fiber bundles. Moreover, this configuration could easily be integrated in order to obtain a more compact structure.

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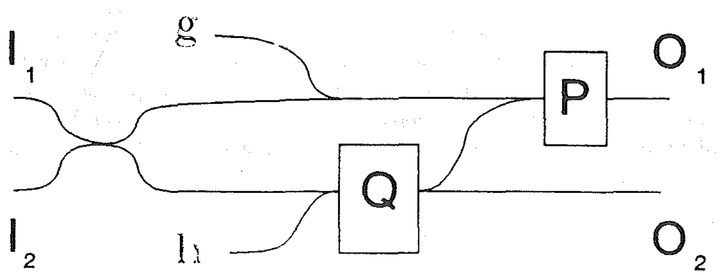

FIG. 1.- Schematic of the Optical Programmable Processing Element (OPE)

Table I. Possible output logic functions

g	O_1	O_2	O_1	O_2	O_1	O_2
g_0	XOR		XOR		NAND	
g_1	NAND		NOR		NOR	
g_2	XOR	AND	XNOR	OR	AND	ON
g_3	AND		OR		OR	
g_4	OR		OR		ON	
h	h_0	h_0	h_1	h_1	h_2	h_2

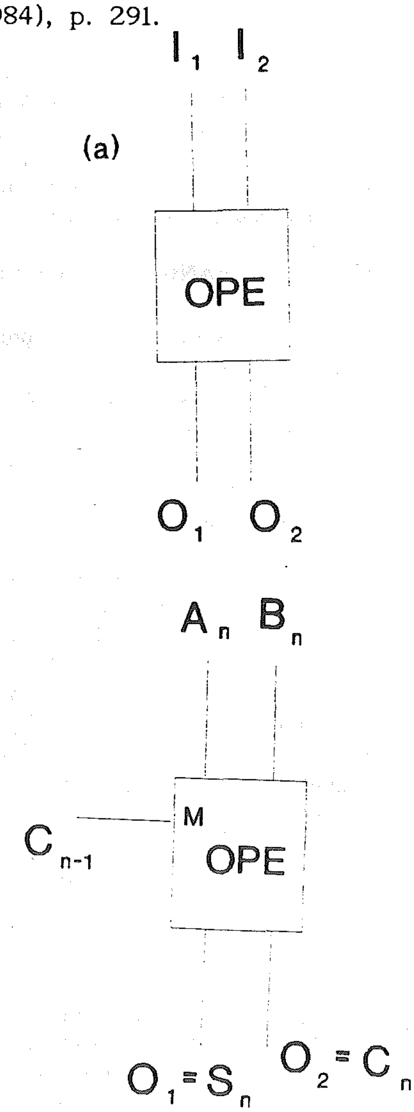

FIG.2.- (a) Half-adder (b) Full-adder